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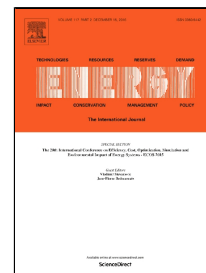
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Highlights

1. This study models energy system of Beijing employing EnergyPLAN model
2. 100% renewable energy system of Beijing is developed in 2030
3. The heating system of Beijing (district heating system and individual heating) is analysed

Energy modelling towards low carbon development of Beijing in 2030

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Abstract

Beijing, as the capital of China, is under the high pressure of climate change and pollution. The consumption of non-renewable energy is one of the most important sources of the CO₂ emissions, which cause climate changes. This paper presents a study on the energy system modelling towards renewable energy and low carbon development for the city of Beijing. The analysis of energy system modelling is organized in two steps to explore the alternative renewable energy system in Beijing. Firstly, a reference energy system of Beijing is created based on the available data in 2014. The *EnergyPLAN*, an energy system analysis tool, is chosen to develop the reference energy model. Secondly, this reference model is used to investigate the alternative energy system for integrating renewable energies. Three scenarios are developed towards the energy system of Beijing in 2030, which are: (i) *reference scenario 2030*, (ii) *BAU (business as usual) scenario 2030*, and (iii) *RES (renewable energies) scenario 2030*. The 100% renewable energy system with zero CO₂ emission can be achieved by increasing solar energy, biomass and municipal solid waste (MSW) and optimizing heating system. The primary fuel consumption is reduced to 155.9 TWh in the *RES* scenario, which is 72 % of fuel consumption in the reference scenario 2030.

Keywords: Renewable energy; energy modelling; low carbon; Beijing.

1. Introduction

Low carbon cities, with low greenhouse gas (GHG) emissions, high renewable energy fraction, and efficient energy unitization are expected to play an important role to achieve the goal of low carbon society. The reason that cities are an important player in the transition to a low carbon society is that they have a high current contribution to GHG emissions. The contributions are projected to continually grow considering population and economic activity growth, and high energy consumption in cities [1-3]. A few low carbon city indicators are promoted to combine national strategy and local development, such as energy use and waste disposal [4]. The energy sector is the largest anthropogenic sources of CO₂ emissions. Energy is also used directly or indirectly in economic activities. The cities consume more than 75% of worldwide energy production and generate 80% of carbon emissions [5]. Cities need various energy supplies without interruption to power economic and social activities of human beings. Angelidou suggested the transition to smart cities should begin now and start by selecting a few domains or high polluted sectors, for example, energy sector, and transportation sector [6]. The transition to low carbon energy faces multiple challenges both for the government and individual citizen. On the one hand, increase the conversion efficiency of

renewable energy and decrease the cost comparing with fossil fuels [7,8]. On the other hand, the individual consumers should also be encouraged to choose renewables over fossil fuels. Rather than seeing challenges as forces of opposition, they are seen as opportunities for renewable energy to grow, improve, and adjust in a way that leaves themselves more competitive better off [9]. The importance of the low carbon energy transition on small scales is pointed out by analysing two case studies [10]. Cities have the responsibility to cut down their carbon emissions and minimize the pollutants to the atmosphere. The reduction of energy consumption even by a small amount at the individual level can translate into large reductions in the amount of energy source that needs to be harvested. The cities and regional governments –both small and large- are in the position to reduce their impacts on reducing energy consumption and improving energy efficiency. The scenarios related to energy demand are modelled, particularly those relating to building environment, transportation, and building and urban utilities [11-13].

In the case of China, the Chinese government signed the Paris Agreement on climate agreement 2016 to cut its carbon emissions per unit of GDP by 60-65% by 2030 from 2005 levels, which was set 40-45% in 2020 in Copenhagen in 2009 [14]. China also aimed to increase the share of non-fossil fuel sources in primary energy consumption to about 20% and peak its carbon emissions by 2030 [15]. The Chinese central government intends to convert the energy system into a sustainable system and a system based on more renewables under the climate change and international and national environmental pressure. This ambitious encourage a growing body of research engaged in exploring the low carbon technologies and GHG emissions reduction in individual cities from different perspectives in China. In the building sector, after reviewing and comparing a few low carbon technologies in an island of China, the authors pointed out *“the most positive effect of implementing the assessed technologies lies in their GHG emission reduction and employment generation”* [16]. Li conducted energy performance and carbon emissions simulation of the city Macau. Both Li and Huang pointed out the solar energy production had the largest potential for carbon emissions reduction by building sector with no surprise [13, 16]. The important parameters of city planning are identified to reduce household GHG emissions from empirical studies of five neighborhoods in Beijing [17]. These studies focused on the specific low carbon technologies integration or assessment. One of the most important requirements of low carbon society is to build sustainable energy system in the city long-term planning [18,19]. Scenario analysis is the common method to predict the potential future progress of several possible energy models both inside and outside China [20, 21]. These studies pointed out the fossil fuel consumption and efficient use of material and energy during urban development can help to discharge the emission of pollutants to the environment. In China, the studies about renewable energy technology or integration of them into energy systems are on the national level instead of city or regions [22, 23]. This is probably due to the fact that, in China, the decision-making structure is a top-down approach especially for the long term planning or strategy [24]. The city’ energy strategy and planning have significant influence in determining the energy and carbon profiles of China. The urban activities contribute the largest share of the total commercial energy consumption, which was more than 80% in 2014 [25].

Beijing, as the capital of China, has high energy consumption and limited energy resources on the contrary. The majority of fuels consumed in Beijing is coal, which has to be transported from coal-rich provinces such as Shanxi, Inner Mongolia, and Hebei. The consumption of coal in energy and industry sectors was to blame for GHG emissions [11, 26]. As it becomes more efficient to transmit electricity compare to transport coal, the government tends to transmit electricity between regions. More than half of the electricity consumed in Beijing is transmitted from these three provinces in 2014 [27]. In the rural area of Beijing, the major energy consumption is for space heating and cooking [28]. It is obvious that the higher energy consumption of fossil fuels is the main cause of GHG emissions. Few studies are carried on exploring the potential renewable

energy scenario of Beijing in the future. The objective of this paper is to model potential energy scenarios with 'zero coal consumption', which is also the energy development strategy of Beijing [29]. It means the alternative energy sources need to substitute coal in the energy system.

Therefore, this paper aims to capture a relatively complete picture of energy scenarios by exploring alternative energy resources and potential GHG emissions reduction in Beijing. This paper is organized in four sections described as below. The first section of this paper introduces the importance of energy use and carbon emissions at the city level. The second section presents the methodology employed to model energy system. Energy scenarios formalization and model development process are elaborated in this section too. The third section presents the results and discussions of the energy scenarios. The conclusion is conducted in the fourth section.

2. Methodology

In this section the methodology applied in this study and energy modeling process is presented. The primary goal of the article is to build an energy system model for Beijing, which covers heat, electricity together with a wide range of alternative renewable energies. The energy analysis structure and scenarios are described followed the advanced energy system analysis computer model *EnergyPLAN*. A reference model is created based on the energy tool *EnergyPLAN*. The developed model is then used as the energy system of Beijing to exploring the low carbon scenarios transition of Beijing society. In our study, the simulation of the energy system could identify the quantitative comparison between reference scenario and new heat strategy scenarios in terms of primary energy consumption and carbon emissions.

2.1 The *EnergyPLAN* model

The *EnergyPLAN* model is an advanced computer tool for modeling energy system. The *EnergyPLAN* model can help in the development of national or regional energy planning strategy based on the technical and economic analysis. This model had been used to model a number of cases of the energy system and 100% renewable energy plans for cities and countries [30-32]. It can also be employed to analyses new heat technology integration in the system [33, 34]. The *EnergyPLAN* is a deterministic input-output energy system modelling tool, which is able to create annual analyses of different energy systems on an hourly level. The structure of the *EnergyPLAN* model is described in Fig.1. The inputs are energy demands (electricity and heat), renewables' capacities, capacities of the individual energy producers, energy mix of thermal power plants and the choice of a number of different energy strategies and regulation. The model requires broad range hourly distributions of electricity and heat demand as well as the distributions for energy productions from the wind, the photovoltaics (PV), river hydro and similar energy sources. In this paper, the electricity hourly distribution data is collected from State Beijing Electric Power Company and the heat hourly distribution is obtained and modified from Beijing District Heating Group. The outputs are energy balances and annual energy productions, fuel consumptions and CO₂ emissions and the share of renewables.

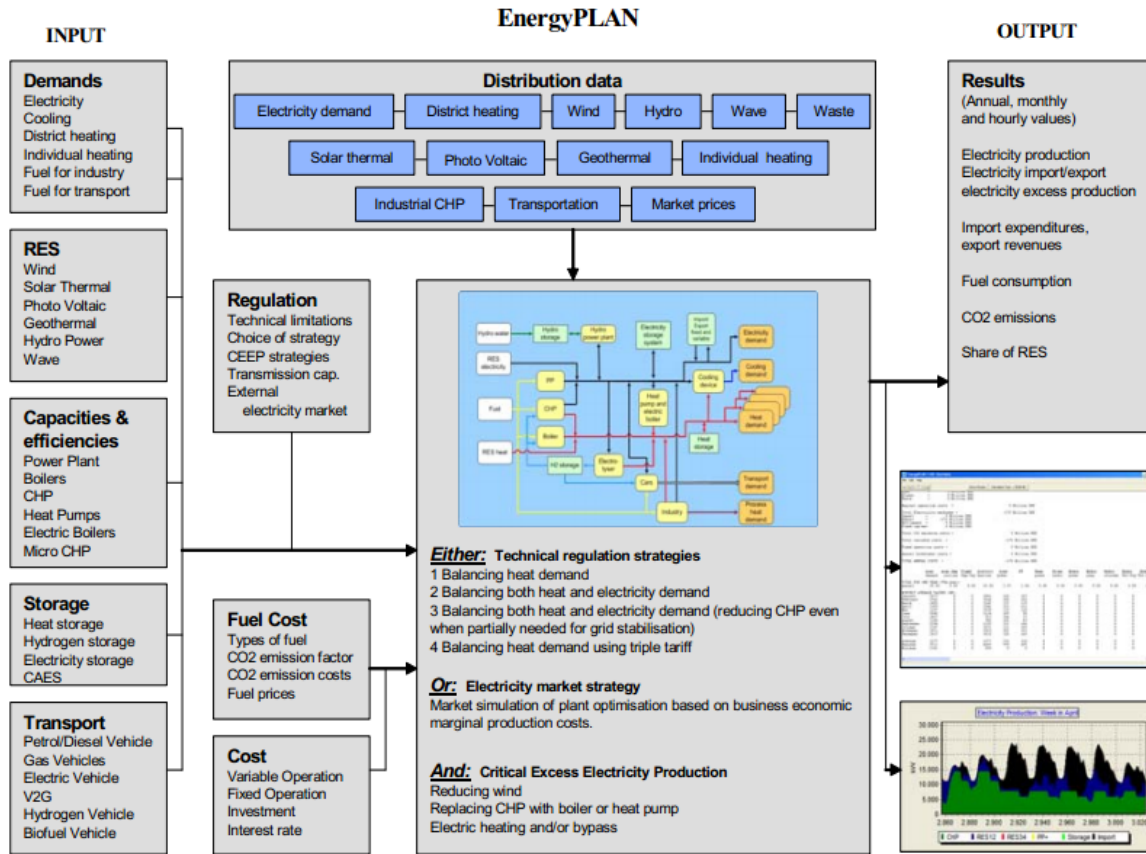


Figure 1. The structure of *EnergyPLAN* [35]

2.2 Model process

The future energy demand is determined by population, economic, and many other factors, which let energy demand hardly predicted [36, 37]. Most of the studies by researchers or organizations predict energy demand by lots assumptions based on scenario analysis [37]. A large amount of electricity can be imported from neighbor power grids to Beijing. The purpose of this paper is to model and compare potential energy situations which are not implemented yet. The comparison will be carried on by primary fuel consumption, the proportion of renewable sources in the system and the total CO₂ emissions from the system. In this study, the electricity production in 2030 is estimated based on the assumption of annually increased rate 1.5 %, which is also the national energy demand increased rate of China by IEA from 2014 to 2030 [38]. This increased rate is also a quarter of the electricity production increased rate of Beijing from the year of 2005 to 2014, which was the fast economic developing period. The electricity production is estimated to be 46.83 TWh in 2030. The heat demand is predicted based on the annual increase rate of 1.56 %, which is a quarter of annual heat demand increased rate of Beijing from the year 2005 to 2014. The total heat demand is estimated to be 62.9 TWh, which includes district heating in the urban areas and individual heating in the rural areas (table.1).

Typical potential renewable energies in Beijing are the solar energy source, which is also the most popular renewable source for heating production in China [39, 40]. The potential solar energy resource is predicted 350TWh in Beijing [41]. The capacity of solar photovoltaics (PV) for electricity generation was 25 MW in 2014. There is no clear statistic data about the total capacity of solar thermal for heating production in 2014. Based on current building area and condition, there will be 700 million m³ building's roofs which are suitable for solar panel [42]. Together with the development of concentrated solar power, solar energy may dominate

the renewable supply potential within urban areas in the future. Another attractive renewable energy source is biomass and MSW. The potential energy production is 6.7 TWh from agricultural and forestry residues, and 16 TWh of energy can be obtained from MSW [41]. Wind energy and hydropower can provide high renewable fractions outside the urban area of Beijing, which is different picture compare with national and regional energy consumption in general [43].

The planning for the energy development of Beijing is ‘zero coal consumption’ in the urban areas. In Beijing, many of coal-fired power plants have been constructed since 2000, meaning that it is technically capable of continuing to operate for decades to come. Even though the Beijing municipality has taken steps to invest in developing and constructing highly efficient natural gas power plants and renewable energy power, and to retire some of its most inefficient existing coal-fired capacity, it is likely not economic realistic to close all the coal-fired power plants considering their high percentage in the current electricity system. The economical option is to find the alternative energy source replacing all the coal from the power plant, the heat plant, and the heat boilers gradually. Technologically, the potential alternative energy sources could be natural gas biomass [44, 45].

In this paper, the timeline is set 2030. The goal is set as ‘no coal consumption’ in the whole municipality of Beijing by 2030. For the purpose of this work, three scenarios have been created (table.1). The first one, reference scenario, it is developed based on the energy situation in 2014, in which the increased electricity and heat consumption is satisfied with the import fossil fuels with no measurement of controlling GHG emissions. The second one, *BAU* (business as usual) scenario presents a policy as usual in which natural gas replace coal in the electricity and heat consumption to reduce GHG emissions from energy system. The third scenario, *RES* (renewable energies) scenario presents a model of the system with unitization of renewables in the form of biomass energy and PV power to replace fossil fuels completely in the energy system.

Table 1. Electricity and heat demand in the scenarios (TWh)

Demand	Reference scenario 2030	BAU scenario 2030	RES scenario 2030
Electricity Demand	46.83	46.83	46.83
Heat Demand	62.90	62.90	62.90
CHP(combined heat and power)	7.53	7.53	19.58
District heating boilers	36.16	36.16	24.11
Individual heating boiler	19.21	19.21	19.21

2.2.1 Modelling reference scenario

In order to create the future scenarios and analyze the energy system a reference model had to be created first. The year 2014 has been used as a reference year since it is the newest year with available data. The installed capacities of the power plants have been taken from the China Electric Yearbook [26]. The total electricity production was 36.9 TWh. The fuels consumed for electricity and heat production are obtained from Beijing Statistical yearbook [46], as well as the energy demands of the building, industry sector. The hourly distribution of electricity demand for the year 2014 had been used here. They were obtained from State Beijing Electric Power Company the meteorological data including outside temperature wind speeds and solar insulations were taken from the report [41].

As can be seen in table 2, the electricity consumed by the city was mainly generated from thermal power plants with only 150 MW of installed wind power, which produced only 0.32 TWh of electricity in 2014. A few amount of hydropower plants was installed in the Beijing energy system, which produced 7 TWh of electricity in 2014. Even though solar energy is the most competitive renewable energy source in Beijing,

there was only 0.02 TWh of electricity produced from solar PV. The heat production includes district heating system (CHP and boilers) and the individual heating boilers. The supply of district heating started from the 15th of November in 2014 to the 15th of March in 2015. The total district heating supply was 53.6 TWh in these four months, which included 15.4 % of heating generated from CHP plants and 84.6 % of heating generated from district boilers. The individual boilers were mainly installed on the countryside, where the individual boilers were used for heating and cooking. The efficiencies of coal and natural gas stoves are 40 % and 50 % respectively, which are much lower compare to the modern stoves [47]. Table 2 presents the results of energy system modelling from the actual energy consumption of Beijing and the *EnergyPLAN* simulation. It shows that the *EnergyPLAN* simulation is closed to the actual energy data in 2014. The difference is below 1 %, which proves that the distribution data and efficiency data used in the model is satisfactory enough to simulate the future energy system of Beijing. The *EnergyPLAN* model is capable of simulating energy system of Beijing accurately. The assumption, which is used to develop the reference scenario 2030, is based on the energy resource distribution in 2014.

Table 2. Validation of the 2014 reference model.

Technology	Fuel input TWh		Difference TWh	difference %
	Actual data 2014	EnergyPLAN simulation		
Electricity production				
Coal	29.29	29.24	0.05	0.17
Oil	0.75	0.75	0.00	0.00
Natural gas	37.76	37.39	0.37	0.98
Hydropower	7	7	0.00	0.00
Wind power	0.32	0.32	0.00	0.00
Solar energy	0.02	0.02	0.00	0.00
Heat production				
Heat production of CHP unit	12.59	12.58	0.01	0.08
Heat production of Boiler	44.13	44.10	0.03	0.07
Individual heat demand	34.31	34.31	0.00	0.00

2.2.2 BAU scenario (business as usual scenario)

The current energy strategy of Beijing is to replace coal with natural gas and to increase the renewable energy portions of the energy system at the same time. Natural gas replacing coal in the energy system can increase fuel consumption efficiency. Based on this principle of the energy strategy, the *BAU* scenario is developed. The detail inputs and technologies are presented in table 3. The potential capacity of wind power and river hydropower could reach 1 GW and 1.5 GW respectively. The heat demand will be provided by district heating system and individual heating system. In the district heating system, 15.6 % of heating demand is met by CHP natural gas plants, 84.4 % of heating demand is supplied by natural gas boilers, which is the same heat distribution to that in the reference scenario 2030. This scenario is created mostly using the known technologies which can be adapted to the current infrastructures. It assumes that the current energy market can develop and improve existing technologies.

Table 3. Details of energy conversion units and input in the *BAU* scenario

Energy conversion technology	Efficiency	Input	
	%	GW	TWh
Electricity Demand		46.83	
Power Plants unit (natural gas)	38.00	1.00	
CHP unit (natural gas)	38.00	4.50	
River hydropower		1.50	
Wind		1.00	
Solar Photo Voltaic		6.00	
CSP Solar Power		1.00	

Heat Demand		62.89
CHP unit (natural gas)	52.00	7.53
District heating boiler		36.16
Electric heating		6.00
Solar thermal		2.00
Natural gas stove	50.00	13.20

2.2.3 RES scenario (renewable energy scenario)

An overview of reference scenario and *BAU* scenario shows that Beijing's energy system will be still dominated by fossil fuels either coal or natural gas. A 100% renewable energy scenario is promoted here to reduce the energy dependence on fossil fuels, in which all fossil fuels are replaced with renewables in the Beijing energy system in 2030. The list of the installed energy technology can be found in table 4. Biomass and MSW as the main renewable energy sources replace fossil fuels for electricity and heat production. The scenario treats heat technologies as significant technologies as the heat production is relatively higher than the electricity production in Beijing as showed in table 1. CHP is global recognized a significant technical choice to improve energy system efficiency [48, 49]. In the *RES* scenario, it is assumed that one-third of district heating boilers are updated by CHP plants.

In the district heating system, the more efficient CHP plants expand their capacity and produce 24.07 TWh of heat, which is higher than that in the *BAU* scenario. The heat production from the district heating boilers decreases to 12.06 TWh, as part of the district heating boilers are replaced by CHP plants. A relatively large amount of the district heating boilers is that the heating system with increasing unbalance in the electricity supply generated by the renewables and the CHP plants, demand the flexibility of the system by installing electric heating and heat boilers. The individual heating system is mainly located in the rural area of Beijing. There are no district heat system infrastructures, so it might take decades to install the district heating system. Electric heating and solar thermal are promoted to replace fossil fuels consumption and to increase energy efficiency.

Table 4. Details of energy conversion units and input in the *RES* scenario

Energy conversion technology	Efficiency	Input	
	%	GW	TWh
Electricity Demand			46.83
Power Plants unit (MSW)	38.00		16.00
CHP unit (biomass + MSW)	38.00	4.50	
River hydropower		1.50	
Wind		1.00	
Solar Photo Voltaic		6.00	
CSP Solar Power		2.00	
Heat Demand			62.89
CHP unit (biomass + MSW)	52.00		31.60
District heating boiler (biomass)			12.06
Electric heating			13.20
Solar thermal			6.00

3. Results and Discussion

After running the simulation for scenarios with the help of *EnergyPLAN*, the results are analysed. The results of three scenarios are presented based on the fuel consumptions, the share of renewable resources for electricity and heat production and CO₂ emission (table 5). As expected the reference scenario has the highest fuel consumptions and CO₂ emissions because of the low efficient heat system and low proportions

of renewables. In the *BAU* scenario, the share of renewables is 11.66 % of total fuel consumptions, thanks to the increased renewables in the electricity production. The primary energy consumption is decreased 32.94 TWh compared to that in the reference scenario which is 216.58 TWh. The CO₂ emission is decreased to 34.19 Mt, thanks to the replacement of coal with natural gas in terms of electricity and heat production. The *RES* scenario is the one with 100% renewables and zero CO₂ emission in the year 2030. Compared to the reference energy system, the *RES* scenario is able to reduce the primary energy consumption to 155.90 TWh. One of the critical issues about renewables especially the solar and wind energy in the energy system is critical excess electricity production (CEEP). Surplus electricity production is defined as situations in which the electricity production exceeds the demand in a given time and area. The electricity production from solar PV cannot change with electricity demand hour by hour [50]. The electricity production from CHP plants depends on the heat demand. In the city of Beijing, the heating system for the residential buildings is only supplied for four months of the whole year. In order to increase the shares of renewables and CHP plants in the energy system and avoid 'surplus electricity production' at the same time, the electric heating and district boilers are designed in the energy system. In these three scenarios, analyses of the energy system based on hour by hour have been used to increase electricity from renewables and CHP to an amount ensuring that the unused electricity consumption is low. These analyses also ensure that the heat supply and electricity supply is balanced. In the *RES* scenario, the expansion of solar energy and CHP plants leads to an excess electricity production 0.76 TWh.

Table 5. Results of the scenario analysis

	Reference scenario 2030	<i>BAU</i> scenario 2030	<i>RES</i> scenario 2030
Fuel consumption (TWh)	216.58	183.64	155.90
RES shares %	3.39	11.66	100.00
CO ₂ emission (Mt)	67.62	34.29	0.00
CEEP (TWh)	0.01	0.23	0.76

Table 5 presents the primary energy consumption by sources to produce the electricity and heat demand. Fig. 2 further illustrates the share of renewables in the scenarios shown in table 5. There are, however, large differences between the scenarios with regard to energy sources and conversion technologies. The reference scenario keeps the same energy source distribution to the energy system of the year in 2014. The major two energy sources are coal and natural gas in the reference scenario. In the *BAU* scenario, the main energy sources are natural gas with few contributions of oil and renewables, which account for approximately 15% and 11% respectively. The energy system of the *RES* scenario is built up by difference renewables mix. The mainly newly installed renewables are solar energy and biomass.

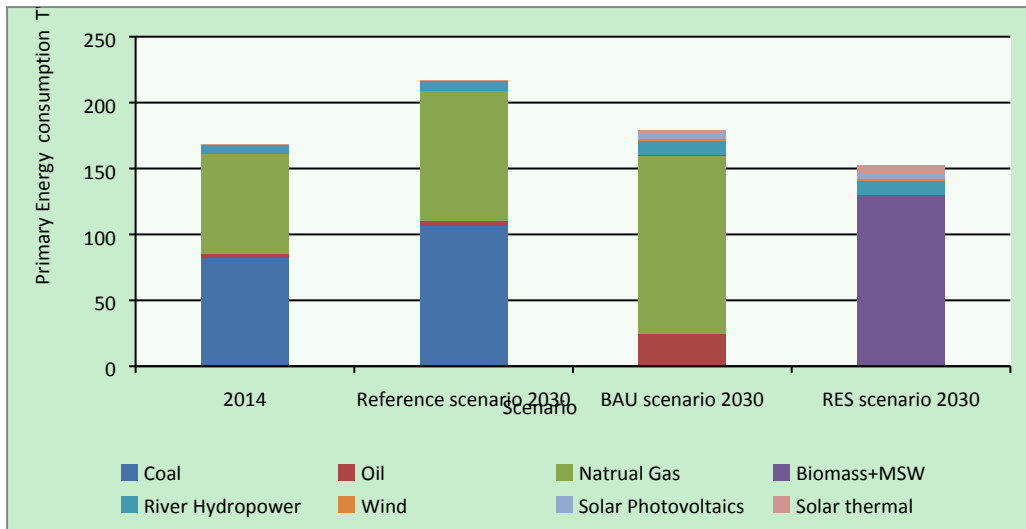


Figure 2. The Primary Energy consumption by different sources Unit: TWh

There is great potential for the solar energy source in Beijing and the government should encourage both industrial and individual consumers to further invest solar energy. In the paper, two approaches are employed to access solar energy, which is solar photovoltaics for electricity production and solar thermal for heat production [50]. As shown in the analysis in this paper, if solar PV installed on all building roofs, the energy production could be 6 TWh. Together with solar thermal energy, the total solar energy can supply estimated 10.18TWh, which accounts for 9.3 % of total energy demand in 2030.

In the *RES* scenario, a 100% renewable energy system is possibly achieved with inputs of 113.93 TWh of biomass and 16 TWh of MSW both in terms of electricity and heat production. The energy utilization of agricultural and forestry residues can increase the harvested rate of biomass, which potentially reduces the environmental impacts to the soil [51, 52]. Beijing is a modern city with limited agricultural land and activity. This determines that there are not enough biomass sources available in Beijing. The biomass sources need to be transported from neighbour provinces, which will cause high impacts from transportation [53]. The overusing biomass for energy purpose could cause the impacts on the land system and ecosystem [54]. The potential conflicts of biomass energy production are due to the different demands and expectations from the land resource, as biomass energy requires the conversion of agricultural land from food crop cultivation to the energy crops plantation. The energy utilisations of waste products from the activities of agriculture and forest, and human-being were highlighted, as they can avoid both direct and indirect land-use change [55]. From conversion technology perspective, the second-generation biofuel technologies were promoted to avoid cultivating biofuels from the arable land [56]. The high proportion of natural gas and biomass in the energy system might cause the price of electricity and heat increasing. The potential economic consequence need to be addressed in the future study.

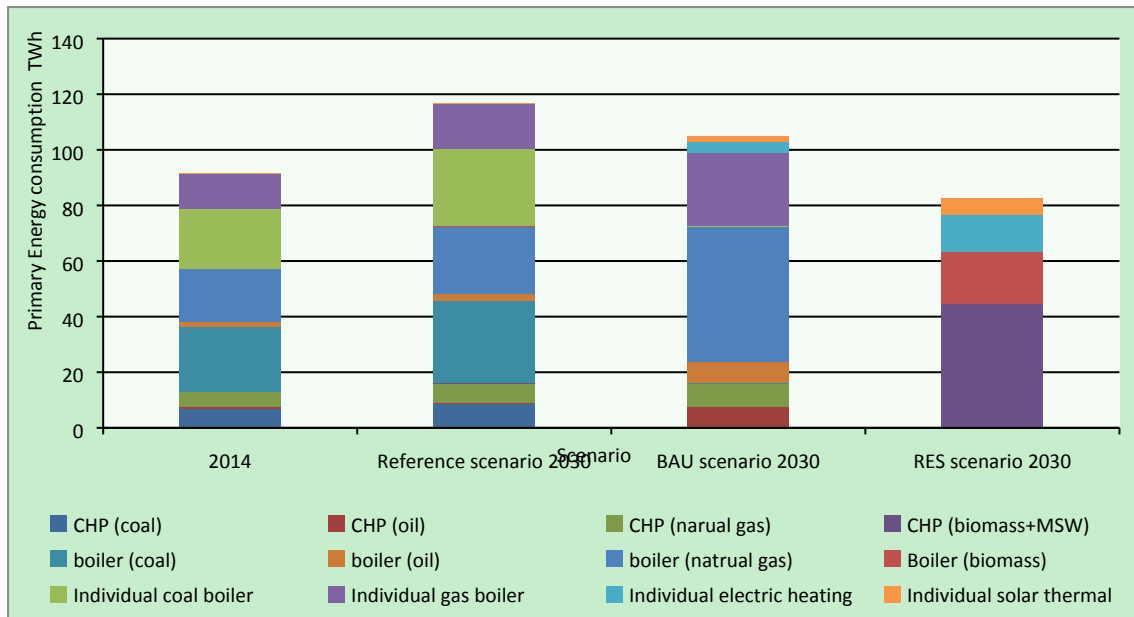


Figure 3. The Primary Energy consumption of heat production by different sources Unit: TWh

Fig.3 presents the primary fuel consumption for heating supply both district heating and individual heating. In the year 2014 and reference scenario, fossil fuels still play the major role in the both district heating system and individual heating supply. The low efficiency of coal boiler and stove cause the high primary fuel input in the two scenarios. Compared to the reference scenario, it is clear that the energy efficiency has been increased with introducing high-efficiency CHP in district system and electric heating and solar thermal in the individual heating system in the *BAU* and *RES* scenarios. The primary energy input is decreased to 105 TWh/year of *BAU* scenario by employing high-efficiency gas boilers. In the *RES* scenario, the primary energy input is decreased to 82.63 TWh/year by introducing electric heating to the individual heating system and increasing the share of CHP plants in the district heating system. In the individual heating system, the traditional conventional boiler is replaced by the demand for electricity which is generated by biomass CHP plants and biomass condensing power plants. The annual primary fuel input is decreased to 19.2 TWh which is 32.4 TWh in the *BAU* scenario and 43.97 TWh in the reference scenario.

The heat productions account for more than half of the primary fuel consumptions in three scenarios in 2030 and also in 2014 in Beijing. So it is important to increase energy efficiency and renewable energy proportion to eliminate fossil fuels in the heating sector. The current heat situation of heating system is diverse due to the local cultural, weather condition, and unbalance infrastructure development between urban area and countryside. High-efficiency technologies like CHP, heat pumps, and solar thermal and traditional low-efficiency technologies like coal stoves constitute the current heating system in China [57, 58]. As there is no district heating infrastructure in the rural area, the heat alternative technology promoted here is electric heating and solar thermal energy for the individual heating system. The result shows the annual primary fuel input in the *RES* scenario decrease 13.2 TWh compare to that in the *BAU* scenario with natural gas stove, a small amount of electric heating, and solar thermal energy.

4. Conclusion

This paper presented the 100% renewable energy scenario of e of simulating the energy system of Beijing relating to electricity and heat. The accuracy of the reference model was validated by comparing the results

of the model with actual statistics of the year 2014. The validation proved that the model is accurate to model the future energy analysis of Beijing. Based on the detailed hourly distribution, three scenarios were developed and analysed, which are reference scenario, *BAU* scenario, and *RES* scenario. With the help of this *EnergyPLAN* model, these three scenarios were analysed and compared regarding renewable energy integration and CO₂ emissions.

The results show the *BAU* scenario and *RES* scenario can help with decrease the annual primary fuel consumption compared to the reference scenario 2030. The reduction of primary fuel consumption is by 15% in *BAU* scenario and 28% in *RES* scenario. The calculated CO₂ emission produced by reference scenario is two times higher than that in the *BAU* scenario where natural gas replaces coal for the electricity and heat production. The energy system of the *RES* scenario developed based on energy sources of solar energy and biomass, and optimization of heat system is 100% renewable energy system with zero CO₂ emission. Results reveal that the most significant low carbon technologies are in the heating sector after comparing the *RES* scenario with *BAU* scenario. The challenge of *RES* scenario is how to balance electricity and heat productions from renewables with other technologies. The analysis highlights the important of the heating system both district heating and individual heating system. First, in the urban area, the district heating system with high efficient technology like CHP should be promoted in the future. In the rural area, the suitable infrastructure for district heating needs to be constructed to improve heat consumption efficiency, which is also calls for a long time horizon. Electric heating and solar thermal are good alternative heating supplies if the electricity is generated from renewables.

It should see that it is very ambitious to have 100% renewable energy system in Beijing in 2030. The transition to 100% renewable energy is a long-term objective. It cannot be reached without an effective policy support. The investment of energy project is a complex and process and need to start from the energy infrastructures both for electricity transmission and heat supply. Further research needs to cover the transport model especially electric vehicles.

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